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Fuzzy Logic Application with MATLAB: Estimating Egg Consumption

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ABSTRACT
This study provides a model that estimates egg consumption using fuzzy logic based on criteria selected. In the model, the parameters affecting the number of eggs were determined initially and input and output variables were defined. In the next step, fuzzification was performed and membership functions were determined. The triangular membership function was selected for the membership function. Then, fuzzy rule base was determined and fuzzy rules were formed. In the next step, the fuzzy inference mechanism was created. The "centroid" method was used for the defuzzification process. In the study, fuzzy logic toolbox was used in Matlab and the results obtained showed the usability of fuzzy logic in estimating egg consumption.
KEYWORDS: *Egg, fuzzy logic, membership, Matlab, income*

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I. INTRODUCTION

Fuzzy Logic was first proposed by Zadeh in 1965. According to Zadeh, fuzzy logic creates more propositions between 0-1 than classical logic's 0 and 1 propositions. The definition of fuzzy sets proposed by Zadeh is different from the classical concept of a member or a non-member of a set. In Zadeh's definition, nothing is absolutely certain in fuzzy logic and fuzzy set theory. If expressed mathematically, everything changes on the boundary between 0 and 1. In the fuzzy set concept, each element in the set is defined as a member to some extent. According to this definition, the "fuzzy cluster" is a cluster with elements of different membership levels. Fuzzy sets can be expressed by ranking the set elements according to their membership degrees and mathematically defining the membership function [1, 2]. With fuzzy logic, an inference structure with knowledge-based, applicable approximation capability is provided. Fuzzy set theory has provided mathematical power that includes uncertainties combined with human cognitive processes such as thinking [3].

MATLAB is a software that is widely used in many areas all over the world with numerical and symbolic calculations, data analysis, highly advanced drawing procedures, algorithm development, advanced programming, engineering and scientific applications [4]. MATLAB, which is estimated to be used by more than 500 000 academicians, researchers and students around the world, is defined as the most advanced technical and scientific problem solving and application development tool of the digital world with its numerous sub-modules called toolboxes, which cover many mathematical and engineering fields [5].

MATLAB provides a fast analysis and design environment that the user can trust. Operations can be made extremely easy with many ready-made functions or functions coded by the programmer [4].

Fuzzy logic has recently gained traction in different researches in many fields. For example, it is used in geophysics [6, 7], for creating a ground description system [8], electromyographic wavelet transformation [9], creating a land valuation model [10], and in the health sector [11].

The aim of this study is to estimate egg consumption with fuzzy logic application by creating input functions and output functions using Matlab program.

II. MATERIAL AND METHOD

Material

The population of the study included people who lived in Bingöl, Turkey and neighboring provinces. However, sampling was made as it was almost impossible to reach the entire population and obtain information about them in terms of time and cost. A study was conducted in February 2020 mostly in Bingöl, Turkey (Van, Diyarbakır and Malatya), and neighboring provinces and the survey was implemented to 220 people. The survey was excluded and the remaining 220 surveys were analyzed.

Method

Fuzzy logic is a superset that expands on the classical binary logic by including the concept of "partially true" in addition to the completely true and completely false. It is a method where fuzzy propositions based on logic are examined by being passed through a logic filter [12].

In fuzzy logic, whether an object is a member of a set is determined by membership functions. Using inference methods used by fuzzy logic, an attempt is made to interpret events. From this, it can be inferred that fuzzy sets are subjective, not objective. The membership degree of the object in the fuzzy set is given by the subjectively defined membership function. The membership degree of an object ranges from 0 to 1. Here, the value of 1 indicates full membership, and a value close to 0 indicates that the object membership in the fuzzy set is weak. That is, the object with a value of 0 is not a member of the fuzzy set. Triangular membership functions are one of the frequently used membership functions in fuzzy logic terminology [13]. The triangular membership function is defined as follows [2].

$$f(x,a,b,c) = \begin{cases} \dfrac{x-a}{b-a}, & a \le x \le b \\ \dfrac{c-x}{c-b}, & b \le x \le c \\ 0, & x \le c \; veya \; x \le a \end{cases}$$

Membership functions can be defined in different ways according to the problem to be solved by the person using fuzzy logic. These are input/data definition, fuzzification, fuzzy rule base, fuzzy inference, defuzzification, and outputs [14].

In this model estimating egg consumption based on fuzzy logic, inputs were defined as monthly income and food expenditure, and outputs were defined as the number of eggs (Table 1). System structure is shown in Figure 1.

Table 1. Input, output and membership functions

	Variables	Values	Membership functions		
Input	Income	2000-8000 TL	Low	Medium	High
	Food cost	500-3500 TL	Low	Medium	High
Output	Egg number	0-135	Low	Medium	High

Fuzzy sets and expressions were formed according to the data here. Fuzzy sets created for each of the input data were formed in the low, medium and high ranges. The income input variable was defined in the range of 2000-8000, the food expenditure variable was defined in the range of 500-3500, and the number of eggs was defined in the range of 0-135.

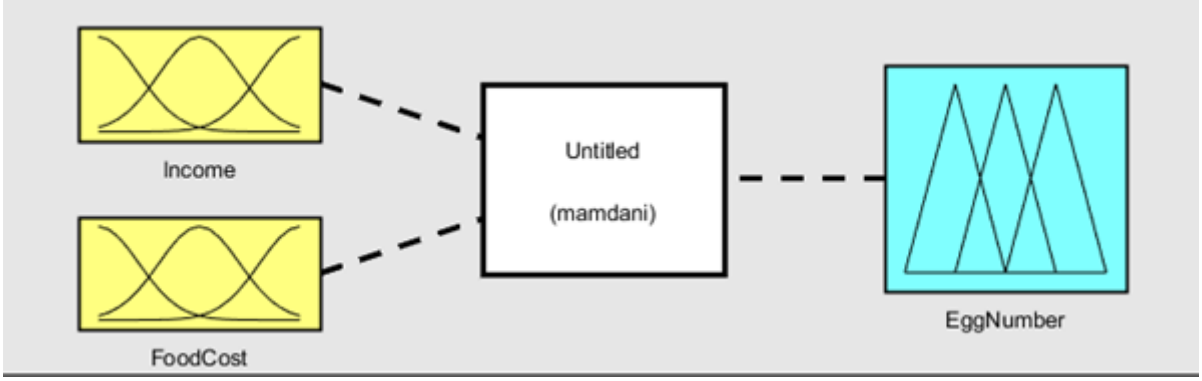

Figure 1. Fuzzy logic based egg count determination

In the system, levels were defined according to value ranges in order to define membership functions. Three levels (low, medium, high) were defined for the income input data, three levels (low, medium, high) were defined for the food expenditure input data, and three levels (low, medium, high) were defined for the number of eggs output data. Membership functions used in the system are shown in Figure 2.

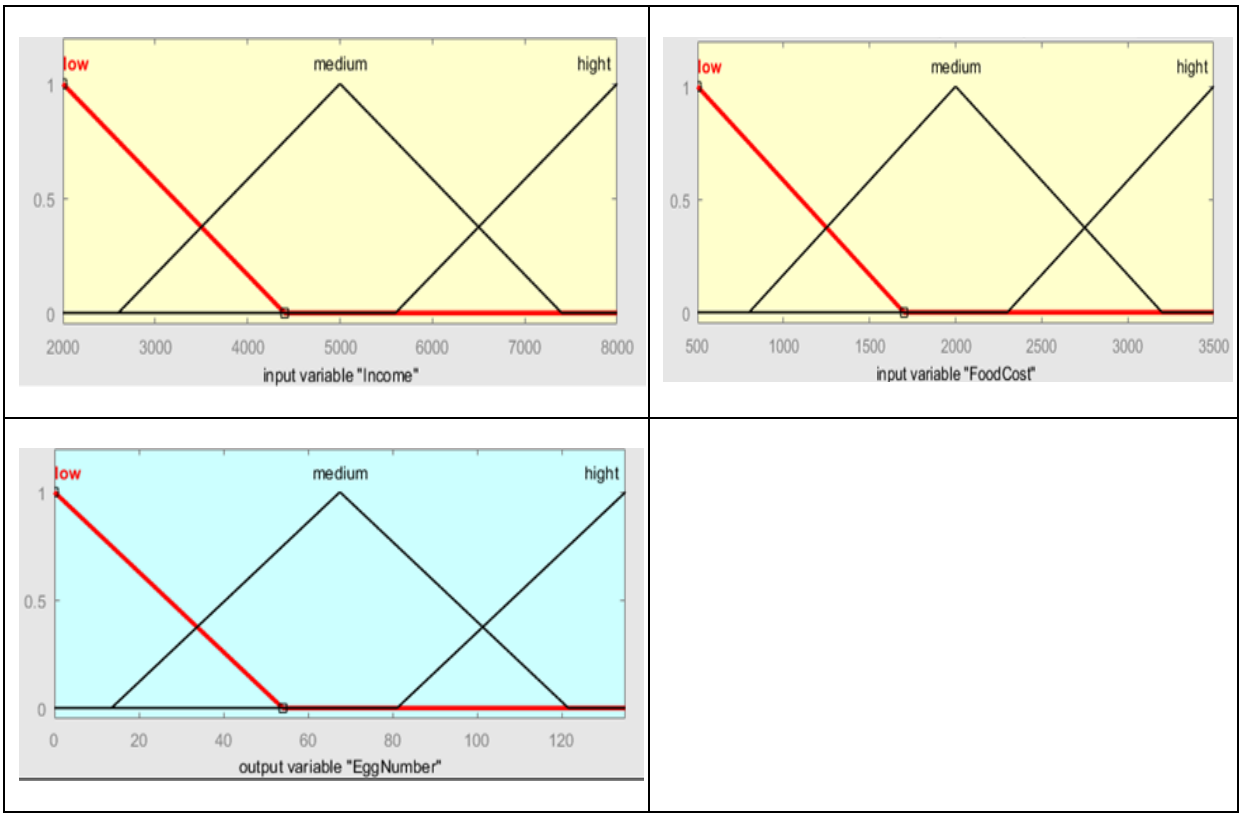

Figure 2. Membership function plots

The analysis of fuzzy logic application was carried out using Matlab Fuzzy toolbox.

III. RESULTS AND DISCUSSION

Socioeconomic and demographic characteristics related to the household chicken meat consumption are displayed in Table 2.

Table 2. Socioeconomic and demographic characteristics of chicken meat consumers

Sex	**Frequency**	**Percent (%)**
Man	125	56.8
Woman	95	43.2
Total	220	100
Age		
<25	93	42.3
25-34	38	17.2
35-44	43	19.6
45-54	26	11.8
55-64	8	3.6
≥65	12	5.5
Total	220	100
Martial		
Married	116	52.7
Single	104	47.3
Total	220	100
Income		

2000-3000 TL	110	50
3000-4000 TL	78	35.5
4000-5000 TL	22	10
5000 TL+	10	4.5
Total	220	100
Food cost		
500-1000 TL	124	56.4
1000-1500 TL	49	22.3
1500-2000 TL	22	10
3000-3500 TL	25	11.4
Total	220	100
Number of eggs consumed		
0-20	128	58.2
21-40	50	22.7
41-60	15	6.8
61-80	9	4.1
81-100	13	5.9
>100	5	2.3
Total	220	100

In the fuzzy logic application, input and output variables were defined to determine egg consumption. The triangular membership function was selected for the membership function. Input variables were income and food cost, while output variable was number of eggs. Figure 3 shows the parameters of the fuzzy model consisting of two input and one output parameter and the modeling of the system in MATLAB R2016b program.

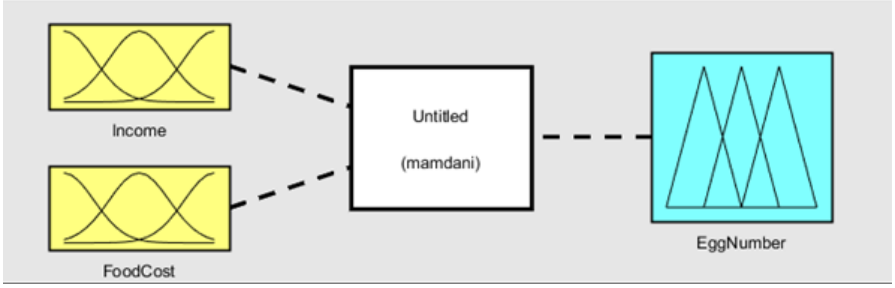

Figure 3. Matlab view of modeling

Graphical representation of "income" input parameter in Matlab is given in Figure 4.

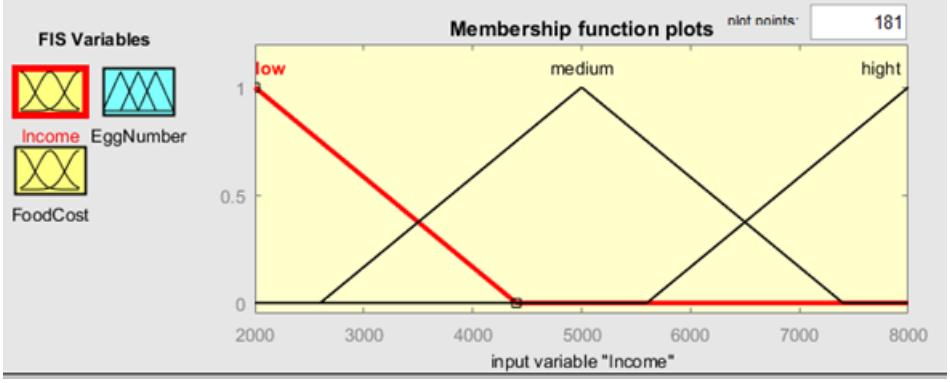

Figure 4. Income input parameter membership functions

Graphical representation of "food expenditure" input parameter in Matlab is given in Figure 5.

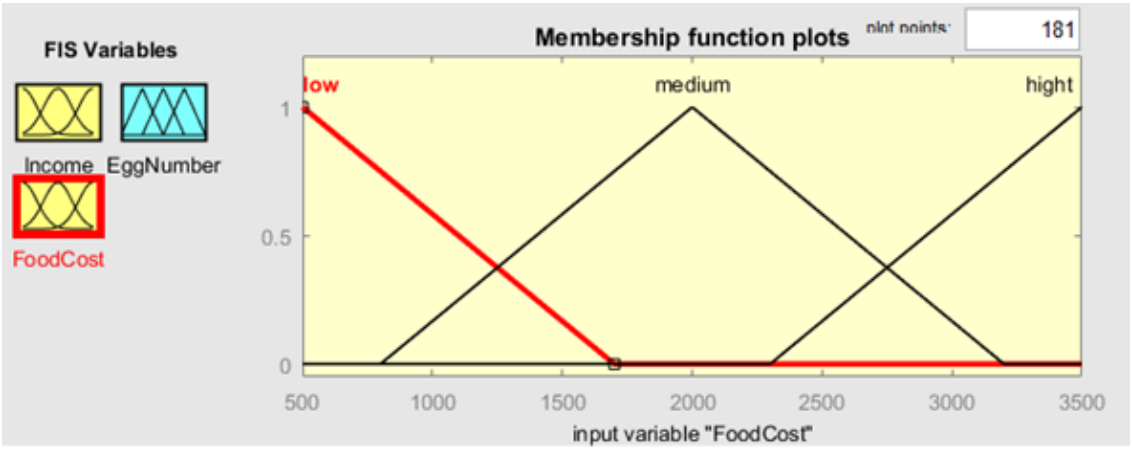

Figure 5. Food cost input parameter membership functions

Graphical representation of "number of eggs" output parameter in Matlab is given in Figure 6.

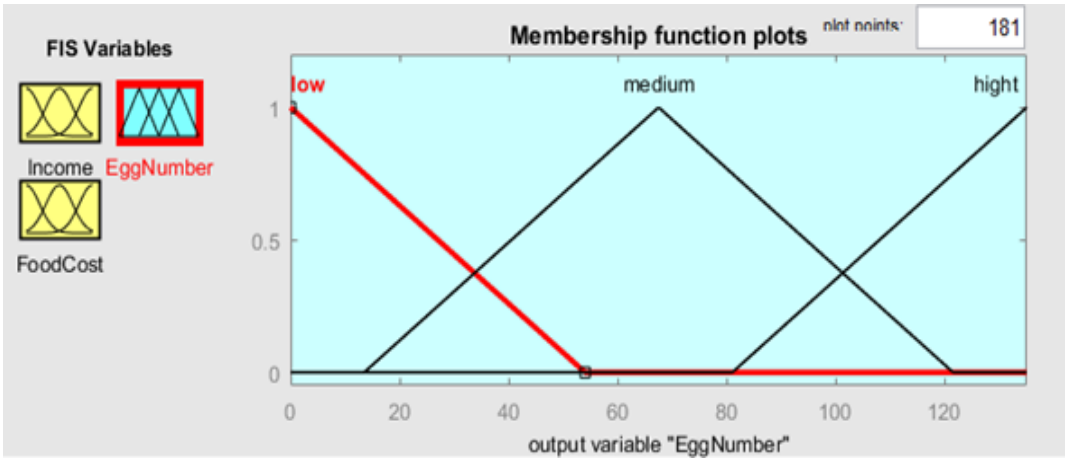

Figure 6. Membership functions of the output parameter of egg number

With the help of the fuzzy rule base, rules were created with the IF - THEN structure for the system to be designed. In order to understand the relationship between the determined membership functions, a fuzzy rule base was created.

Numerous rules were created that make the relationship between input and output parameters easy to understand. All possibilities are included in the knowledge base created, and the rule base of the fuzzy model in MATLAB R2016b program is shown in Figure 7.

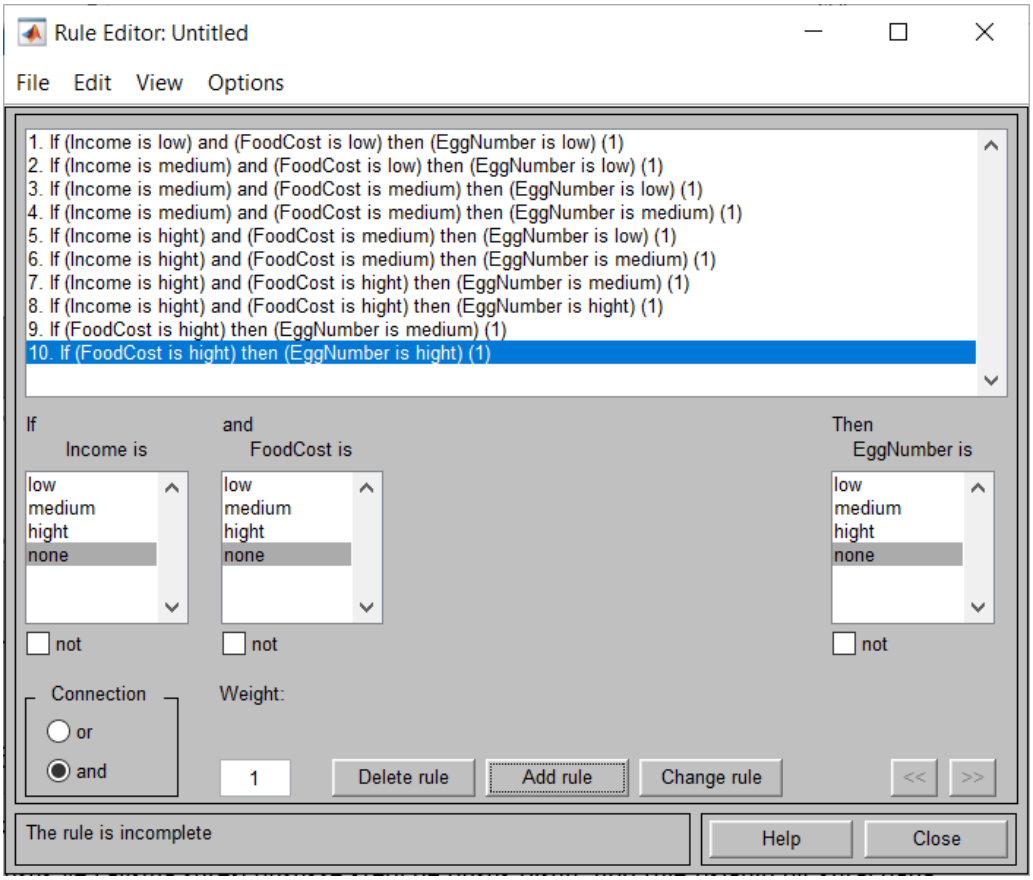

Figure 7. Fuzzy rule base

The image of the process of estimating the number of eggs with fuzzy logic approach in MATLAB R2016b program is shown in Figure 8.

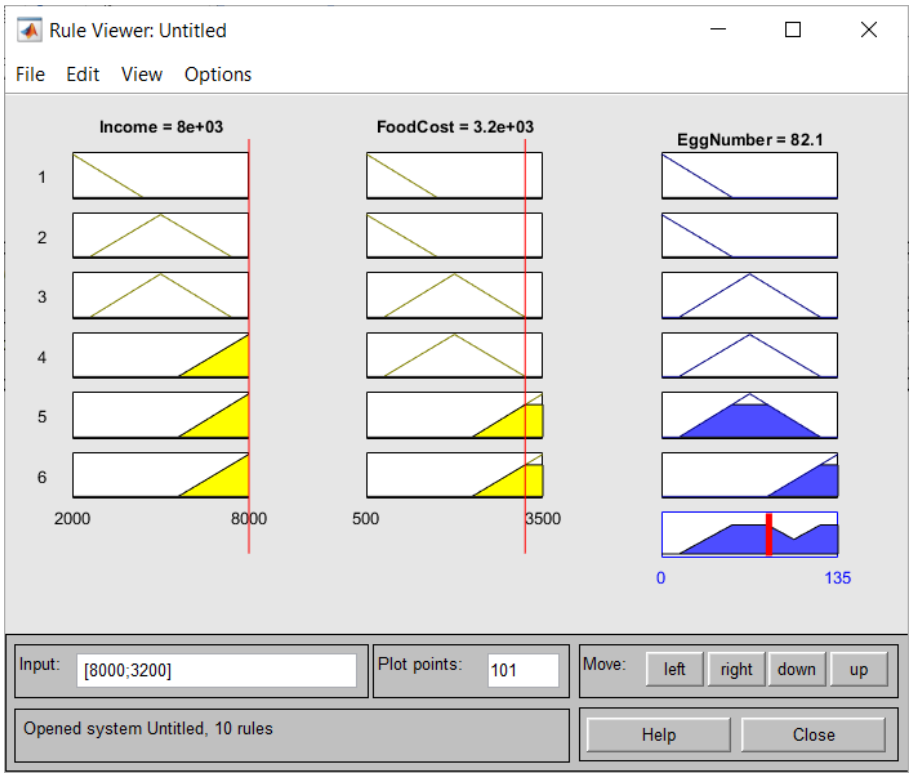

Figure 8. The defuzzification screen for the decision-making process of the model

As seen in Figure 8, the number of eggs, which is the output variable, can be estimated by taking income and food expenditure, which are the input variables, into account. Here, when the income is 8000 TL and the food expenditure is 3200 TL, the number of eggs consumed per month will be 82.1. Egg consumption can be estimated by using various values for income and food expenditure variables. According to this rule base, the number of eggs estimated by the model using different values for income and food expenditure is presented in Table 3.

Table 3. Number of eggs estimated according to input variables

Income	Food cost	Number of egg
4900	2200	52.6
2800	1200	36.7
3000	1000	40.8
6000	2900	74.5
5700	2800	70.2
6800	2700	64.8
7500	3000	81.3
6300	3000	78.4
5400	2600	67.5

As seen in Table 3, individuals with higher monthly income and more food expenditure consume more eggs.

The effect of input variables on output variables according to the fuzzy rule base is given in Figure 9.

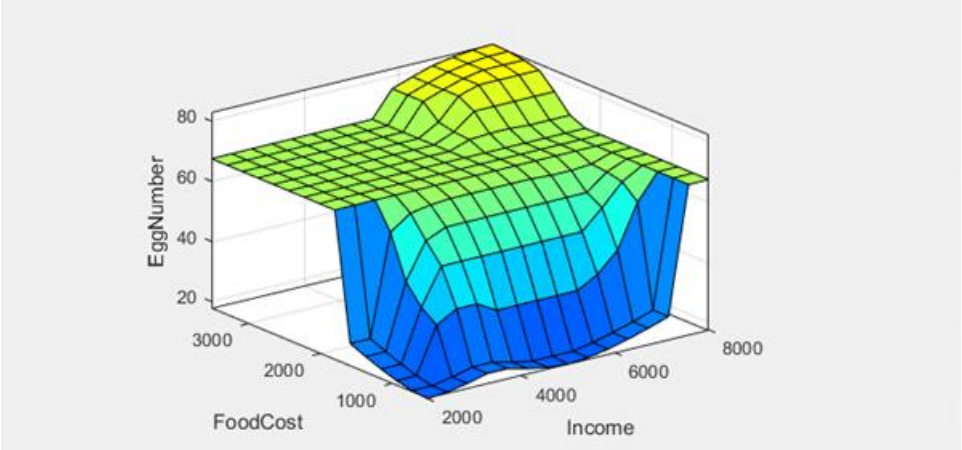

Figure 9. The effect of the exit of input variables to the rule base

When Figure 9 is examined, it is clearly seen that the number of eggs increases as the numerical ranges of Income and Food Expenditure input variables increase.

In a study on egg consumption, it was found that 91.9% of 345 university students consumed eggs, average number of eggs consumed was 3.4 per week, and 91.2% of the eggs were consumed at breakfast [15]. In another study, a questionnaire was conducted on 384 consumers in the province of Uşak in Turkey, and Chi-Square analysis was performed between some variables and income levels. It was found that the number of eggs consumed in the province of Uşak was below the Turkey average and the egg weight was found to be between 53 and 72 g [16].

IV. CONCLUSION

In this study, a fuzzy logic model was established for the estimation of egg consumption using the information on income and food expenditure. In the model, income and food expenditure were used as input variables, while the number of eggs was used as the output variable.

In order to understand the relationship between input and output variables, a fuzzy rule base was created. Mamdani type was used as the mechanism of inference. Centroid method was used for defuzzification. The system was modeled in MATLAB.

In this study, a model was created to estimate the monthly number of eggs consumed by individuals using fuzzy logic. The maximum number of eggs consumed by individuals per month was estimated to be 117 when income was 8000 TL and food expenditure was 3500 TL. It has been observed that the fuzzy logic model

can provide successful results in estimating the consumption level of a product according to the monthly income and food expenditures of the consumers.

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